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Intelligent tobacco flue-curing method based on leaf texture feature analysis

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ABSTRACT

Most traditional curing systems are manually or half-artificial operated that requiring the curers to observe the state of tobacco leaves frequently. A novel intelligent real-time curing control system is developed in this paper by acquiring the optical image of tobacco leaves and extracting the color features and texture features to predict and control the temperature and humidity of the curing barn. The tobacco leaves changes from green to yellow and shrinks gradually, and this changing regulation would enhance the intelligence of tobacco curing system. The proposed neural network is designed to predict the set-point values of the adjustment of dry-bulb temperature, wet-bulb temperature and the changing time, which has eleven inputs include three color features, three texture features, ideal dry-wet temperature, ideal wet-bulb temperature, current stage, stage passing time, tobacco leaves varieties and flag. Some experiments are induced and the experimental results show this proposed approach based on color features and texture features could improve significantly the accuracy than that of the similar method only using color features especially in post-curing process.

1. Introduction

Intensive tobacco curing systems have been widely used in the tobacco industry, due to the advantages of high quality, simple operation and energy saving [1]. The whole curing process usually is divided as three different curing stages, namely, yellowing stage, color fixing stage and stem-drying stage according to the changing color of the tobacco leaf. The quality of tobacco in each stage are dominated by many factors, such as the set-points for dry and wet bulb temperatures, the duration of current curing stage, and the dehydration speed of tobacco leaf [2,3]. In order to meet the required conditions, the tobacco curing process curve is pre-embedded in a curing machine, which drives the actuators including air blower and ventilating fan to maintain the appropriate temperature and humidity in the curing barns. However, the tobacco growing in various soil and climate condition would be very different, and it objectively requires that the temperature and humidity should be adjusted according the status of tobacco leaves. The traditional curing systems require curers to observe the states of the tobacco leaves whenever necessary and decide the time to manually change from one stage to the next one according to prior knowledge and personal experience [4]. In fact, the conventional half-artificial systems have following disadvantages [5]: (1) Limited observation. The curers observe the conditions of tobacco leaves through a small window every two or three hours, and it would occasionally lead to inaccurate judgment and delayed decision. (2) Subjectivity: The status of leaves are

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estimated only relying on the curers' experience, even curers may make incorrect decisions due to excessive tiredness, poor condition and weak eyesight in the evening. (3) Heavy workload: too many curers need to be employed to guarantee systems operated normally. Therefore, it is of great significance to develop an intelligent curing system that can automatically control the process in real-time without relying on subjective estimates from curers.

The rich experience that the curer owns from the field working is the principle to develop the intelligent curing system. The curers observe the conditions of tobacco leaves and even smell the odor emitted from tobacco, and then decide to adjust the temperature and humidity by changing the dry and wet bulb temperatures. Image features extracted by image processing technology from tobacco leaves can represent the curing conditions of the tobacco leaves [6,7], and they could be utilized to adjust the dry and wet bulb temperatures in real time [8]. Most researches have focused on quality evaluations, moisture detection and leaf classification [9–12], and little research has been done to extract the features of tobacco leaves during curing in order to adjust the temperature and humidity in real time. Song et al. [8] analyzed morphological features including shape, color and texture features during whole curing process, but it couldn't be adopted to cure tobacco in real time since it acquired the tobacco image by removing a tobacco leaf from the curing barn and taking a photograph of the leaf in a special cabinet. Zhang et al. [13] presented an intelligent tobacco curing control approach by means of identifying the state of tobacco leaves via extracting the color feature in hue, saturation and lightness (HSI) color space. However, the detailed rules to adjust the temperature and humidity were not given in this paper, what' more, it was not robust since the fuzzy control approach relied greatly on curers' prior experience. Wu et al. [5] proposed an intelligent control system for flue-curing barns to monitor the status of tobacco leaves based on the real-time image color feature extraction of tobacco leaves, and then predict the setpoints for the dry and wet bulb temperatures, and the time to change to the next setpoints by a neural network. Nevertheless, its error between the predicting value and the real value diverged in the post-curing process of color-fixing and stem-drying stage for the color of tobacco leaves changed slowly. A matter of fact, the shape characteristics changed rapidly and the texture features of tobacco leaves should be the principal information during the last two stages [8]. It is desirable to develop an intelligent tobacco curing method that can automatically cure the tobacco by combining the color feature and the texture feature to further improve the quality of curing tobacco especially in color-fixing and stem-drying stages.

In this paper, a new intelligent real-time curing control method is developed by extracting image color and texture features of tobacco leaves and then making decision to adjust the temperature and humidity of the curing barn in real time through learning the advanced knowledge of curer by neural network during the curing process. The remainder of the paper is organized as follows. The intelligent tobacco curing system is reviewed in briefly in Section 2. How to extract the color feature and texture feature of tobacco leaves is explained in Section 3, and the approach to adjust the temperature and humidity based on neural network is discussed in Section 4. Some experiments are included in Section 4 to evaluate and compare the performance of the proposed approach and other methods in Section 5. Finally, the conclusions of the paper are summarized in Section 6.

2. Leaf feature-based curing control system

The tobacco leaves were placed by loose-leaf loading in the bulk curing-barn, which was 8000 mm in length, 2700 mm in width and 3500 mm in height. The curing-barn usually can be load with up to 5000 kg of tobacco leaves. Two color CCD cameras with wavelength of 400–700 nm were installed at the wall near the observation window, and it was protected in a vacuum insulation heat shield (operating temperature range: $-50\,^{\circ}C \sim +150\,^{\circ}C$) for the temperature range in the bulk curing-barn would be more than 70 °C. Meanwhile, the bulk curing-barn was illuminated by two 30W incandescent lamps fixed onto the wall of the barn to keep enough light in the working area of camera so that the acquired image of tobacco leaf has normal color. The curing barn had a dry-bulb temperature sensor and a wet-bulb temperature sensor, which were used to measure the current dry and wet bulb temperatures in the curing barn, respectively. During the curing, the tobacco leaves were flue-cured and controlled according to the dry and wet bulb temperatures, which were pre-set as three stages working flue curve and also be manually altered by the curers. The schematic of the bulk curing barn is shown in Fig. 1.

The developed intelligent tobacco curing system is composed of the design of acquiring tobacco leaves image, the image preprocessing and features extraction method and the approach to predict the set-point values, and the corresponding flowchart is shown in Fig. 2. The neural network collected the information such as the setpoints of dry and wet bulb temperature, changing time setting, color features and texture features and wet-bulb temperature to learn the experience of the curers, and then automatically adjust the setpoints of dry and wet bulb temperatures based on the real-time tobacco leaves images and the measured dry and wet bulb temperatures in the barn.

The tobacco image acquisition system is shown in Fig. 3. The color camera are mounted on the camera platform, and they are controlled by the sever computer via RS485 bus protocol to capture tobacco image with normal color and brightness.

3. Tobacco leaf feature extraction

The color feature and the shape characteristic are the principle information that the curer focus on during he observes the tobacco leaves, and they are also the major features that the intelligent tobacco curing system adopted to control the temperature and humidity in the curing barn. Meanwhile, the image quality usually is affected by light disturbance during